

The use of solar energy for residential buildings in the capital city

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Abstract. Taking into account the conditions of sharply continental climate of Russia the implementation of the project of heating for an apartment house can be structured on the basis of solar vacuum collectors. A diagram of the operation of the vacuum solar collectors can be considered for heating and hot water. The calculations of effective angle of solar collectors also vary for stationary use in winter and summer. Consumption of centralized heat in the spring and autumn is reduced by 30 % due to the use of solar collectors. In summer the main problem of application of solar collectors is to protect the tubes from overheating. In winter, the use of solar heating is able to provide not more than 25 % of the needs regarding the utility and the results of experimental exploitation. It is shown that the main problem of using solar energy in Russia relies not in technology, but in the legislative field. The use of a vacuum manifold in Russia will be widely implemented in areas with a cold climate and in the modern houses after solving the issues of legislative support from the state and municipal authorities.

1. Introduction

Involvement of renewable energy sources in energy production is a modern trend in all industrialized and in many developing countries [1]. The extent of the practical use of solar, wind, biological energy and low-grade heat reached in some countries is extremely high level, commensurate with the level of the traditional installations on organic and nuclear fuel [2]. The modern installations of renewable energy use many of the achievements of science and technology of the 21st century and stimulate a new knowledge, supporting the creation of equipment of the 6th technological structure. Additive and information technologies that enable the creation of new mass and low-cost products, remote control and monitoring, efficient system of storage and conversion of energy are increasingly used in machines and renewable energy systems [1, 2]. Commercial products of the energy range, especially power plants that use renewable energy becomes one of the most popular entries of goods, covering consumers in all countries of the world and with maximum added value. The Russian Federation is currently not among the world leaders in the development of renewable energy (unlike nuclear industries, which managed to keep the leading position). One of the problems hindering the use of renewable energy in Russia is the harsh climate of the greater part of the country [3].

In this work we present the results of application of solar energy in the harsh climate of the Ural regions for heating and hot water for an apartment house that allows us significantly (20–25 %) to reduce the consumption of fossil fuels and environmental impact on densely populated areas of the city. It is shown that in the period of summer repairs and installation of district heating systems



solar heat generation is able to provide 100 % amount of power supply for the purposes of hot water. Experimentally proved the necessity of using special heat-generating equipment with a high degree of repossessions. Practical use of solar energy in Russia is currently the greatest application in the Krasnodar region [4] consisting a high level (DDHP degree-days of heating period) – 3500. Sverdlovsk region has much harsher climate (6000 DDHP) therefore, there exists a high risk of using solar collectors.

To investigate the efficacy of using solar energy in the Ural region the scheme has been developed and executed by the experimental installation of solar collectors with vacuum tubes [5] for heating and hot water. The obtained experimental data clarifies the effectiveness of the system of production of thermal energy for the conditions of sharply continental climate, characteristic of the Ural-Siberian climate zone. In the course of the study- the advent of solar radiation, change in thermal characteristics of elements of the unit; calculated energy performance and efficiency of the installation, the general scheme have been shown in Figure 1.

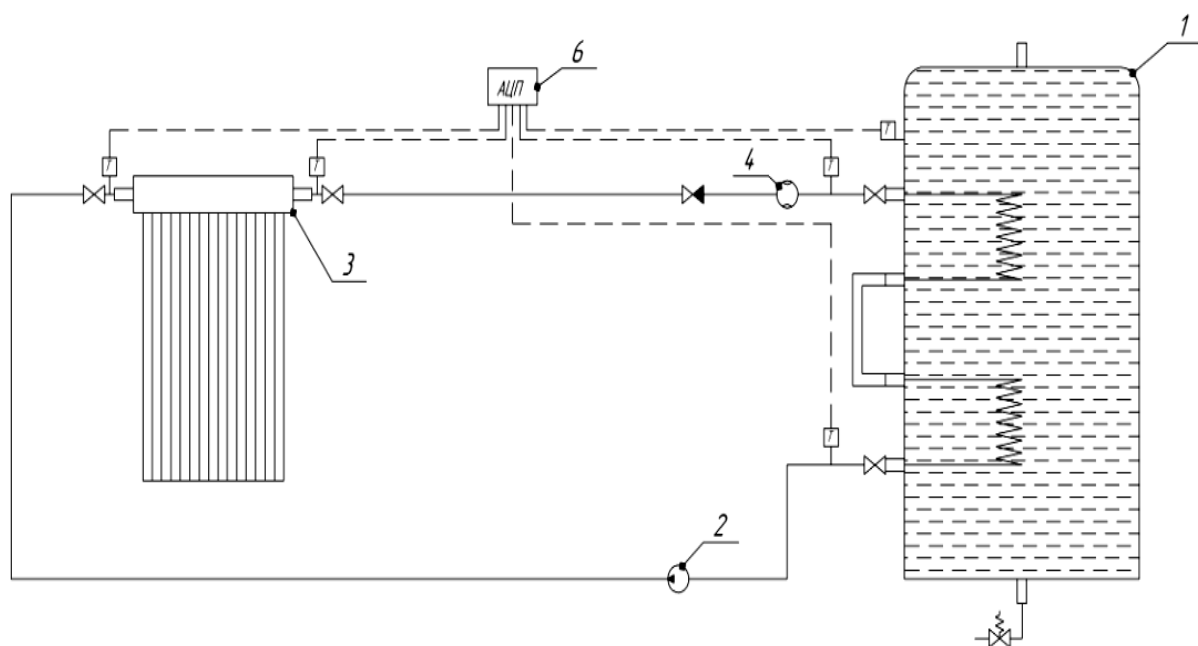


Figure 1. The schematic diagram of the setup to investigate the efficacy of vacuum solar collector under natural conditions of Ural region (Urfa, Ekaterinburg)

- 1 – double circuit storage tank capacity of 250 liters; 2 – circulation pump Wilo 48 W with three-way adjustment-power; 3 – vacuum solar collector Ariston Kairos VT-15; 4 – flowmeter;
6 – analog-to-digital Converter

2. Research setting

Studies of the energy characteristics of the long term (several months) installation, collection and accumulation of information - both the solar radiation and temperature characteristics have been automated.

For the study the radiation characteristics were applied to two independent automatic weather complex (made in USA), recording direct and scattered radiation, temperature and humidity environment, the strength and direction of wind in the automatic mode saving the data in the computer's memory. Solar collectors had a southern orientation and fixed tilt angle to the horizon of 45°.

3. Installation

In April 2012, on the basis of calculations and experimental data the scheme and installation of vacuum solar collectors on a 10-storied apartment building in Ekaterinburg [6]. Diagram of the vacuum system of the IC is presented in Figure 2.

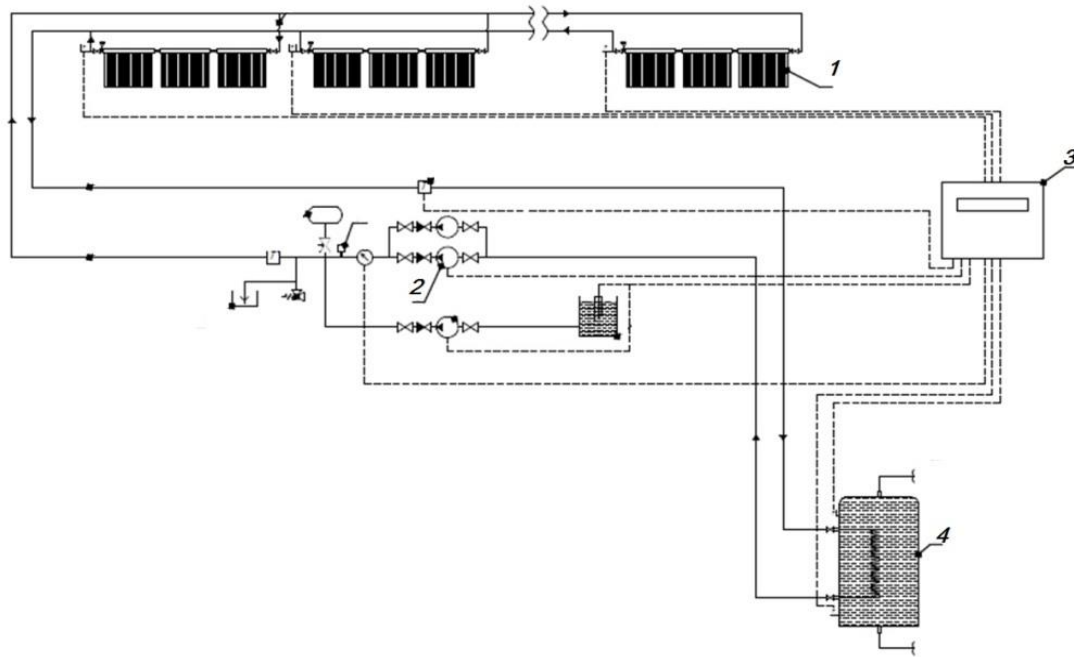


Figure 2. System diagram of a solar heat supply of apartment houses in the metropolis (Ekaterinburg, Rhodonite str., 8)

1 – Solar collectors with vacuum tubes; 2 – a pump for supplying coolant; 3 – controller; 4 – accumulator

Flat SK, as it is known, lose more heat into the environment in comparison with vacuum solar collectors [7]. These losses grow up with the increase in temperature difference. Vacuum solar collectors have a lower area ratio of absorption to total area (60–80 %) in comparison to flat plate collectors. Based on the values of effective area per square meter, vacuum collectors are more efficient. This allows their use in tight spaces on the roof of multistoried residential building.

The selected installation type (solar collector) is determined taking into account climatic conditions. In regions of temperate and cold climate (if any solar radiation) flat collectors will carry significant heat loss due to convection. This fact makes their use impractical. On the other hand, the layer of vacuum tube collector allows to save thermal energy.

From a technological point of view, the process of manufacturing a vacuum manifold (especially with the heat pipes) is more complex and therefore more expensive compared to flat systems.

System with flat plate collectors are widely used in countries with large values of daily sums of solar radiation (Israel, China, India) [8]. In Russia the flat solar collectors are used in the Krasnodar region. On the other hand, they provide hot water (mostly individual households) and are the most cost-effective investment, since they have a relatively low cost.

To solve simultaneously the tasks of providing hot water and heating, it is necessary to have a high temperature coolant and the opportunity to work in winter conditions, and in cloudy weather.

Largely these requirements can be met by the system vacuum collectors with heat pipes. Heat transfer from the heat pipes is more efficient and allows the installation to operate in a wide range of weather conditions. In Figure 3 shows a part of vacuum installation SC on an apartment building in Ekaterinburg.



Figure 3. Photo frame for installation of solar vacuum collectors at an apartment house in Ekaterinburg

The dependence of thermal energy (E) obtained per day against the temperature difference between the coolant in the reservoir and the ambient temperature ($T_m - T_a$) for different values of the advents of solar energy presented in Figure 4 (“SRCC”).

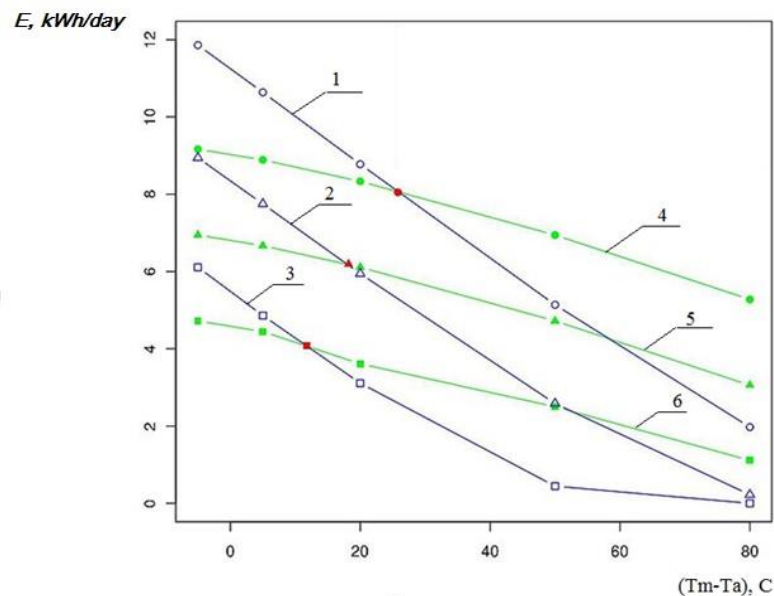


Figure 4. The dependence of thermal energy (E) obtained per day against the temperature difference, between the coolant in the reservoir and the ambient temperature

1 – flat SK, Sunny, $Asun = 6,4 \text{ kWh}/(\text{m}^2 \cdot \text{day})$; 2 – flat SK, cloudy, $Asun = 4,7 \text{ kWh}/(\text{m}^2 \cdot \text{day})$; 3 – flat SK, cloudy, $Asun = 3 \text{ kWh}/(\text{m}^2 \cdot \text{day})$; 4 – vacuum SK, Sunny, $Asun = 6,4 \text{ kWh}/(\text{m}^2 \cdot \text{day})$; 5 – vacuum-UK cloudy $Asun = 4,7 \text{ kWh}/(\text{m}^2 \cdot \text{day})$; 6 – vacuum-UK cloudy with a chance of $Asun = 3 \text{ kWh}/(\text{m}^2 \cdot \text{day})$

The presented dependence figure illustrates the main differences between two types of systems. So, the flat solar collectors (curves 1–3) have large energy service with small temperature difference. However, with the increase of temperature in a solar collector, heat losses grow up, consequently

useful power output is reduced. On the other hand, the curves of vacuum solar collectors (4–6) have a more flat look. This gives an indication of lesser heat losses with increasing temperature.

Thus, taking into account the advantages and disadvantages of both systems, for the project of using solar energy for apartment building the system with vacuum solar collectors consisting heat pipes are selected as the main elements

4. Calculations

Figure 5 presents the power comparison of solar flux for 4 different values of angles of inclination to the horizon system vacuum of solar collectors. The maximum amount of energy during the summer period is observed for angles of inclination less than the latitude (in our geographic location lat 56°), whereas for the winter period larger angles.

For solar energy systems whose main task is heating, the most appropriate angles for "winter" are (inclination from 60 to 70 degrees). For example, for the angle 65° in January observed solar insolation is 400 W/m², while at the same time for angle 10 degrees $I_R = 180$ W/m². Further increase in angle is impractical because when the angle to 90° $I_n = 415$ W/m² for January, but in the summer there is a significant shortage of energy, because solar radiation falls on a vertical surface only partially.

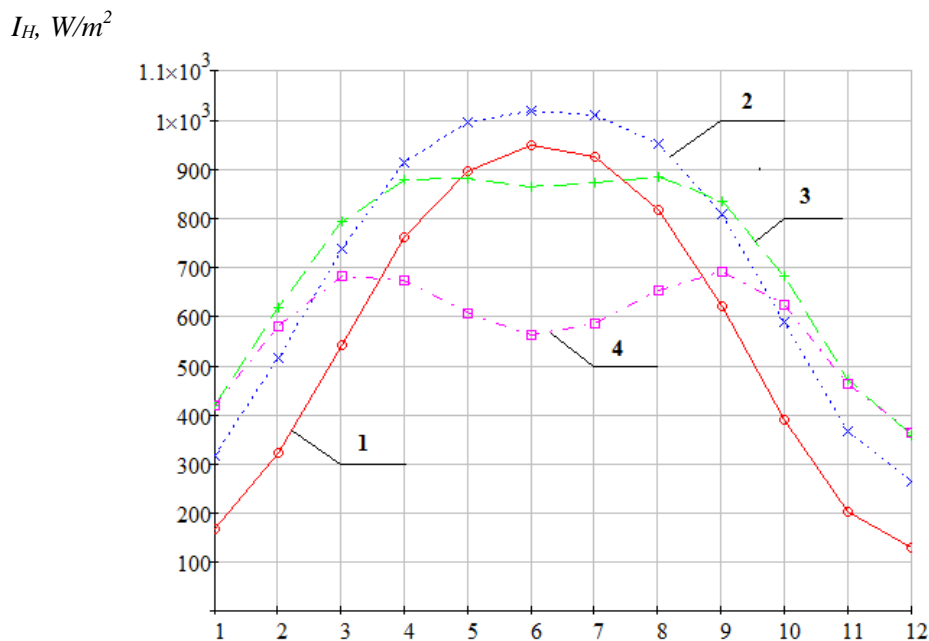


Figure 5. The calculated dependence of the power flux of solar radiation in different months for different tilt angles of solar collectors: 1 – 10°; 2 – 45°; 3 – 65°; 4 – 90°

Thus, for the system of solar collectors used for heating and DHW for a residential apartment house in the conditions of the Urals Federal district, the considered effective angle was 65°.

5. Flow control

In addition to the automatic control system of performance controlled by temperature, the implementation system of data collection (Figure 6) which allows us to display the control screen data for the temperatures of the individual sections of the vacuum SK as well as other parameters, such as pressure and temperature of straight pipe. The availability of such information allows us to monitor the performance of the system in whole and its separate elements. Further information is supplied to the computer, where it is processed and stored in a database that allows us to collect statistical information about the whole system in different periods of the year.

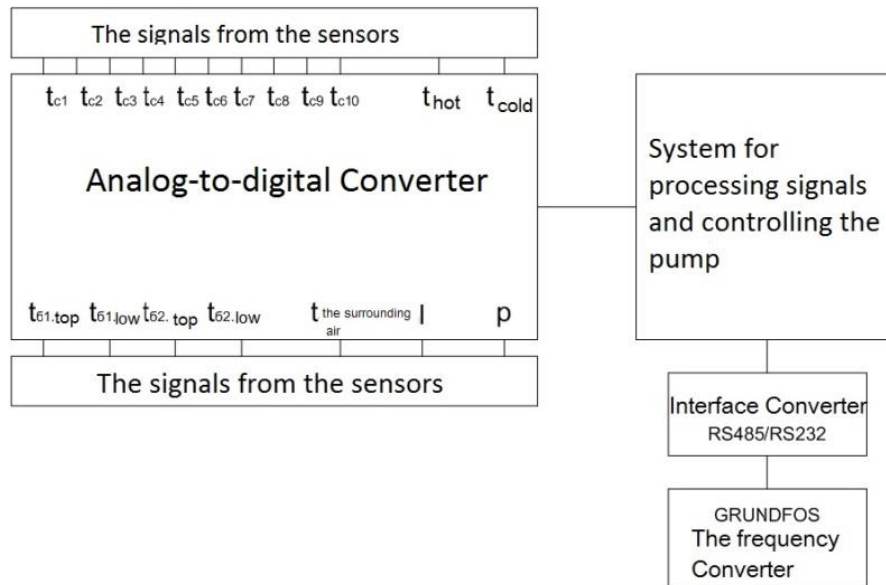


Figure 6. A block diagram of a data collection system, where $t_{c1}, t_{c2}, \dots, t_{cn}$ the temperature of each section headers; $t_{61-top}, t_{61-bottom}, t_{62-top}, t_{62-bottom}$ The bottom temperature in tanks-accumulators; t_{hot}, t_{cold} – temperature in pipelines, p – system pressure, I – power flux of solar radiation

Vacuum installations SC on a block of flats in the metropolis are presented in Figure 7.



Figure 7. Installation of vacuum solar collectors on multi-10-storied building in Ekaterinburg (Students of the UrFU on the practical training for installation)

6. Conclusions

1. Experimentally confirmed the possibility of using solar energy for heating of residential buildings in the metropolis for the conditions of sharply continental climate in the Ural region.

The Operation of vacuum tube solar collectors in an apartment building for 1.5 years has demonstrated the efficiency of hot water and heat supply in autumn and spring.

In the summer, coolant and anti-solar protection are over heated because of no necessity of heating there were required vacuum tubes.

In winter, the system is unable to cope with peak loads (outdoor air temperature from -15 °C and below) and requires the supply of heat from centralized heat supplier.

2. The main problem of the use of solar collectors in the metropolitan areas is the lack of a legislative base for renewable energy and the associated relationship between the consumer (tenant) and a supplier (heat Supply Company). The heat supplier raised a question about the complete shutdown of the centralized system of heat supply and removing it from service or the elimination of a system for solar heating and domestic hot water, as there could be financial losses of up to 30 % in autumn and spring periods.

3. The use of renewable energy sources reduces the city budget advantageously by strategical saving of fuel resources. However, the gaps in Russian Legislation and lack of will of the leadership is not yet possible to overcome the barriers for implementation of solar collectors in the metropolitan areas.

4. The use of vacuum collectors in Russia will start to be introduced widely in areas with a cold climate and in smart houses after resolving the issues of legislative support from the state and municipal authorities. It will open wide opportunities for the construction of smart city with the use of solar energy for heating purposes.

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